

## **ARTHROSCOPIC REPAIR OF THE CAPSULOLABRAL COMPLEX FOR ISOLATED POSTERIOR SHOULDER INSTABILITY**

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### **Objectives:**

The utility of arthroscopic stabilization of the capsulo-labral complex in treating anterior instability of the glenohumeral joint is well documented. However, the effectiveness of similar repair techniques for the treatment of posterior shoulder instability remains unclear. The purpose of this study was to evaluate the clinical results of arthroscopic repair or stabilization of posterior capsulo-labral complex for treatment of isolated posterior instability of the shoulder.

### **Methods:**

A retrospective review of patients who underwent arthroscopic stabilization for posterior subluxation or dislocation of the glenohumeral joint was performed. Twenty-seven shoulders in 26 patients were included. All patients reported a traumatic event prior to the onset of pain and instability symptoms. Patients with anterior instability were excluded. All patients were male. Mean patient age was 28.7 years (15-55 years). Preoperative examination for posterior shoulder instability (under anesthesia) was as follows: 1+ (13 shoulders), 2+ (11 shoulders), 3+ (3 shoulders). The posterior capsulo-labral complex was detached from the glenoid rim in all cases. Bioabsorbable tacks (25 cases) or bioabsorbable staples (2 cases) were used for the repair.

### **Results:**

Mean follow-up was 5.1 years (range: 2 -11.7 years). At followup, all patients were evaluated by a single examiner. Radiographs of the affected sholder were obtained. The L'Insalata Shoulder Rating Questionnaire and the SF-36 quality of life assessment scale were used for functional outcome scoring. Pain and instability symptoms were eliminated in 24 (92%) patients. There were no objective abnormalities in range of motion or stability. Slight external rotation weakness (grade 4/5) was noted in 2 (8%) patients. One patient (4%) reported symptoms of persistent instability and required subsequent open posterior stabilization. The mean L'Insalata score (maximum 100 points) was 90+13.9 (range: 50-100). The mean SF-36 physical component summary score was 50.4+7 (range: 37-61); the mean SF-36 mental component score was 53.9+9 (range: 31-63). The mean SF-36 physical & mental component score is 50 for normal healthy individuals. There was no correlation between radiographic findings and functional scores. There was no evidence of glenohumeral joint degeneration noted on followup radiographs.

### **Conclusions:**

Arthroscopic repair of the posterior capsulo-labral complex eliminates the symptoms of posterior shoulder instability.

## **BILATERAL STRENGTH NORMALIZATION AFTER HAMSTRING TENDON ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION**

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### **Objectives:**

Effective rehabilitation and restoration of function after anterior cruciate ligament (ACL) reconstruction are, in part, dependent upon the restoration of lower limb strength. Bilateral strength normalization, defined as strength of the reconstructed limb being within 10% of the contralateral limb is the rehabilitation milestone. However, the use of bilateral strength normalization as an endpoint is based upon an assumption that the contralateral limb is unaffected during the time between ACL rupture, subsequent reconstruction and rehabilitation process. The purpose of this study was to examine the validity of this assumption by comparison of bilateral lower limb strength after ACL reconstruction to an age and activity matched control group.

### **Methods:**

Subjects were recruited that had an ACL reconstruction with a hamstring tendon autograft (n=12) and compared to an active control group (n=30). Bilateral knee flexor and extensor strength was evaluated using isovelocity dynamometry at five speeds, through a 90° range of motion (5-95°) and for both eccentric and concentric contractions. Subjective self-reported function was assessed using a modification of the Quality of Life with ACL Deficiency Form (Mohtadi 1998).

### **Results:**

After hamstring tendon ACL reconstruction and subsequent rehabilitation, bilateral strength normalization is achieved by the knee extensors. The knee flexors of the ACL reconstructed leg show a statistically significant strength deficit when compared to the contralateral uninjured leg. When compared to an age and activity matched control group, the knee extensors and knee flexors of both the ACL reconstructed and the contralateral uninjured leg demonstrated large and statistically significant strength deficits. A positive correlation was observed between concentric knee extensor peak moment and subjective quality of life assessment.

### **Conclusions:**

These findings limit the validity of using the contralateral leg as a control in the ACL reconstructed population, and identify bilateral strength normalization as a milestone and not an endpoint of rehabilitation. The role of de-conditioning, variation in rehabilitation protocols, and neurally mediated effects on the existence of contralateral strength deficits after ACL reconstruction has yet to be determined. Recommendations are made to modify pre-surgical and post-surgical rehabilitation programs in order to minimize the identified strength deficits.

## **AN EVALUATION OF THE PROVOCATIVE TESTS FOR SUPERIOR LABRUM ANTERIOR POSTERIOR LESIONS**

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### **Objectives:**

A prospective, randomized study was undertaken to determine the most effective provocative maneuver with which to diagnose superior labrum anterior posterior (SLAP) lesions.

### **Methods:**

The following tests were included: active compression, anterior slide, pain provocation, crank, relocation, Hawkin's, Neer, Speed's, and Yergason's tests. A series of consecutive patients scheduled to undergo diagnostic arthroscopy were examined preoperatively with each of the above tests. The final diagnosis in each case was made arthroscopically.

### **Results:**

A total of 132 patients were included in the study, 40 of whom had either a type I (17) or a type II (23) SLAP lesion. The remainder of the diagnoses included complete rotator cuff tears, partial rotator cuff tears, impingement, and instability. The two most sensitive tests for type II SLAP lesions were the active compression (65.2) and Hawkin's tests (65.2) followed by Speed's (47.8), Neer (47.8), and the relocation test (43.5). None of the remaining tests had a sensitivity greater than 17.4% for type II lesions. When Type I and Type II lesions were combined the sensitivities were similar for all of the provocative tests. However, none of the sensitive tests were specific for either type II lesions alone or when type I and II lesions were combined. There were no significant differences between the tests when positive and negative predictive values were assessed.

### **Conclusions:**

Our results contradict the current literature regarding provocative testing for both stable and unstable SLAP lesions. There is no single physical exam test that can accurately diagnose SLAP lesions. However, a combination of the active compression test, Hawkin's test, Speed's test, the Neer test, and the relocation test may all be used to improve the diagnostic acumen of the clinician. Diagnostic arthroscopy remains the gold standard in the diagnosis of superior labrum anterior posterior lesions.

## **A BIOMECHANICAL COMPARISON OF TIBIAL INLAY AND TIBIAL TUNNEL PCL RECONSTRUCTION TECHNIQUES: ANALYSIS OF GRAFT FORCES**

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### **Objectives:**

Controversy exists regarding both the tibial attachment and the site of the femoral tunnel placement for PCL reconstructions. We sought to determine differences in graft forces with two techniques of PCL reconstruction and two femoral tunnel positions.

### **Methods:**

12 cadaver knees had a load cell attached to the femoral origin of the PCL. Bench loading tests were performed under constant tibial loading conditions and the resultant PCL force was measured. A tunnel PCL reconstruction was performed using a B-PT-B graft that was centered in the native PCL's femoral footprint (TC–tunnel central). The bench loading tests were repeated while the graft force was measured. The graft was then repositioned with the femoral attachment located eccentrically (TE – tunnel eccentric, centered in the origin of the anterolateral PCL bundle), and testing was repeated. The graft was removed and a tibial inlay PCL reconstruction was performed. Testing was repeated with the two femoral tunnel positions as described.

### **Results:**

Graft forces with both reconstruction techniques were significantly higher than the native PCL forces beyond 80 degrees of knee flexion; graft forces with the tibial tunnel technique were significantly higher than the tibial inlay technique beyond 80 degrees of flexion. With the tibial inlay technique, graft forces with the central femoral tunnel were significantly higher than the eccentric femoral tunnel at -5 degrees only.

### **Conclusions:**

1.) Between -5 and 90 degrees of flexion there was no difference in graft forces between the tibial tunnel and tibial inlay reconstructions. However, between 95 and 140 degrees the tibial inlay reconstruction resulted in lower graft forces. This finding may be clinically significant as the tibial inlay graft may see lower cumulative loads during the post-operative period which could result in less graft stretch out and reconstruction failures over time. 2.) The central femoral tunnel position generated statistically higher graft forces only from -5 to 0 degrees (although forces were higher from -5 to 90 degrees) when compared with the eccentric hole. The use of a centrally placed tunnel in lieu of a solitary eccentric tunnel (standard femoral tunnel located at the origin of the anterolateral bundle of the PCL) may result in earlier graft elongation and clinical failure. 3.) In spite of attempts to place the femoral graft origin and tibial insertion of the PCL reconstructions in the most anatomically correct positions, the graft forces consistently exceeded the intact ligament forces at higher degrees of flexion.

## **POSTERIOR CRUCIATE LIGAMENT RECONSTRUCTION USING THE TIBIAL INLAY FIXATION TECHNIQUE: TWO-YEAR MINIMUM FOLLOW-UP**

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### **Objectives:**

We performed a retrospective review of 17 cases of isolated or combined PCL reconstruction using the direct tibial inlay fixation technique with minimum 2 yr f/u.

### **Methods:**

The study period was from 1991-1998. 2 year minimum f/u was 96% and averaged 32 months. 12 patients were male and 5 patients were female. Average age was 28 years. There were 13 primary and 4 revision reconstructions. 75% were combined reconstructions. All reconstructions were performed with B-PT-B graft which was 12-18mm in width (8 autograft: 9 allograft). Wider grafts were prepared from allografts. All patients were evaluated with preop and postop exam and x-rays. Preop and final f/u 1999 IKDC subjective eval, final follow-up 1999 IKDC objective eval and final f/u TELOS stress radiography were performed in all patients.

### **Results:**

Average preop subjective IKDC score was 29.3 (1-57). Average final f/u IKDC subjective score was 83 (62-97). This was statistically significant ( $p < .001$ ). All patients evaluated their knee as greatly improved and would repeat the procedure. Preop posterior drawer exam demonstrated greater than 2+ posterior translation in all patients. Postop posterior drawer exam demonstrated the following: normal-4 patients, trace-4 patients, 1+-5 patients, 2+- 4 patients and none > 2+. 16 of 17 demonstrated a solid endpoint on clinical posterior drawer testing. TELOS stress radiography with 20kg posterior load applied at 80-90 degrees of flexion demonstrated average side to side difference 4.7mm (0-10) without correcting for radiographic magnification. Average flexion loss was 5 (0-15). Preop IKDC objective eval rated all knees as severely abnormal. Final f/u IKDC eval was as follows: 7 knees normal/nearly normal, 7 knees abnormal, 3 knees severely abnormal.

### **Conclusions:**

Reconstruction of the PCL with autologous or allograft B-PT-B graft using tibial inlay fixation was shown to be a successful technique at minimum 2 yr f/u. Based on initial experience with this technique and previous experience with open and arthroscopic techniques using a transtibial tunnel, we continue to use the tibial inlay technique as our preferred technique for isolated or combined reconstruction of the PCL.

## **ARTHROSCOPIC BANKART REPAIR WITH A KNOTLESS SUTURE ANCHOR: TECHNIQUE AND RESULTS**

*Raymond Thal, MD (Reston, VA)*

### **Objectives:**

A prospective evaluation of 27 consecutive patients with traumatic anterior instability of the shoulder treated with arthroscopic Bankart repair using a Knotless Suture Anchor is reported. A technique for repair is described. Results at a minimum 2-year follow-up are reported (range 24-39 months).

### **Methods:**

The study population consisted of 24 males and 3 females at an average age of 28 years (range 17-59). Twelve of the patients were 22 years of age or younger. The dominant shoulder was involved in 18 of the cases (16 right, 11 left). The average duration of preoperative symptoms was 66 months (range 3 – 192 months) all with an initial traumatic event. All patients had recurrent instability. Twenty-one patients had preoperative dislocations (average 4 dislocations) and 6 patients had recurrent subluxations. Five of the 6 patients with an associated SLAP lesion underwent SLAP lesion repair at the time of the Bankart repair.

### **Results:**

All of the patients reported satisfaction with the performed surgery. All but one patient remained stable during the follow-up period without feelings of apprehension or episodes of subluxation or dislocation. Twenty patients (74%) regained full range of motion post-operatively. Twenty-five patients (93%) had less than 5 degrees loss of external rotation at 90 degrees of abduction. Two patients had 10 degrees loss of external rotation. No patient had more than 10 degrees loss of external rotation. The average loss of external rotation was 2 degrees. One patient (3.7%) experienced a traumatic redislocation 1 year post-repair. He was asymptomatic until he dislocated his shoulder when he fell skiing. He remains stable following revision arthroscopic Bankart repair using knotless suture anchors.

A total of 92 anchors were inserted during this study. Three anchor loops broke during insertion. Two of the 3 broken anchor loops occurred in first 3 cases performed. Repair was successfully achieved by stacking another Knotless Anchor into the same drill hole in each case. No other technical complications were experienced.

### **Conclusions:**

The described technique for arthroscopic Bankart repair using the Knotless Suture Anchor provides a suture anchor repair without arthroscopic knot tying. We found this technique consistently provided a secure, low-profile repair. Minimum 2 year follow-up results demonstrate a low re-dislocation rate and excellent maintenance of range of motion.

## **ALL ARTHROSCOPIC VERSUS MINI OPEN REPAIR IN THE MANAGEMENT OF TEARS OF THE ROTATOR CUFF**

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### **Objectives:**

Small series have shown all arthroscopic repair feasible, however, comparative series to document these reports' assertions that these procedures provide improvement in perioperative morbidity or outcomes are limited. Presented here is a prospective report to compare all arthroscopic repairs with mini-open rotator cuff repairs by a single surgeon.

### **Methods:**

From 1/91 to 3/99 770 patients were taken to surgery for rotator cuff repair; 490 had moderate or large tears or other diagnoses and were excluded, leaving 280 patients for review. 126 chose an all-arthroscopic repair versus 154 with an open repair. Follow-up averaged 36.3 months for the arthroscopic and 47.8 for open with a minimum of two years.

### **Results:**

Age, gender, associated findings at surgery, and duration of surgery were not significantly different between the two groups. Perioperative morbidity was significantly decreased with all arthroscopic repair, allowing 98% to be performed outpatient versus 38% ( $p < 0.01$ ) and significantly less narcotic use. Recovery of motion was not significantly different at any time of follow-up. There were two manipulation and four reoperations for failed repair in the open group (4%). Four patients had loose anchors early in the arthroscopic group; this complication ceased early using second-generation anchors. Three failed repairs presented with a total reoperation rate of 4.76% ( $p = ns$ ). Final outcomes as measured by ASES, UCLA and SST scores were not different.

### **Conclusions:**

All arthroscopic repair is shown to offer a significant reduction in perioperative morbidity over mini open repair. Final outcomes are not changed, and early complications indicate a steep learning curve.

## **A RANDOMIZED PROSPECTIVE CONTROLLED CLINICAL TRIAL EVALUATING THE EFFICACY OF PHYSICAL THERAPY IN POST-OPERATIVE ROTATOR CUFF REPAIR OUTCOMES.**

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### **Objectives:**

Despite the importance of post-operative functional recovery, the optimal form of rehabilitation after rotator cuff repair surgery has yet to be determined. This clinical trial is the first to compare outcomes for patients receiving either individualized physical therapy treatment or a standardized home exercise regime after rotator cuff repair surgery.

### **Methods:**

63 volunteers, with all sizes of operatively repaired rotator cuff tears were randomized to either the physical therapy group or home exercise group. All patients received the 6 month home exercise regime. Patients who were randomized to the physical therapy group also received individualized treatment (mean = 15 treatments) designed to restore normal shoulder arthrokinematics. Outcome measures of range of motion (ROM) and muscle strength were selected according to the results of prior inter-rater and intra-rater reliability trials. The Western Ontario Rotator Cuff Index (WORCI) was included for assessment of patient satisfaction. Independent blinded assessment was performed pre-operatively, and at 6, 12, 24 and 52 weeks post-operation for all patients.

### **Results:**

Patients who were admitted to the physical therapy group (n = 35) and home exercise group (n = 28) were matched for gender, age and tear size. Statistically significant results ( $p < 0.05$ ), as determined by t-tests and ANOVA with correction for multiple comparisons for the various outcome measures, included - At 6 weeks, the physical therapy group had greater active external rotation ROM (goniometry) and greater passive flexion ROM (visual estimation). At 6 weeks, the home exercise group reported improved physical symptoms and sport capacity (WORCI). At 12 weeks, the physical therapy group had greater active hand behind back ROM (tape measured distance) and reported improved physical symptoms (WORCI). At 24 weeks, the physical therapy group reported improved physical symptoms, work function and lifestyle (WORCI). Power analysis indicated potential for further significant outcomes favouring the physical therapy group with a sample size of 100. Interestingly, 32% of patients allocated to the home exercise group have dropped out of the trial and have taken up physical therapy of their own accord.

### **Conclusions:**

For the present sample size there is both objective and subjective evidence supporting rehabilitation via physical therapy for patients who have undergone rotator cuff repair surgery.

## **HAMSTRING GRAFT FIXATION FOR ACL RECONSTRUCTIONS: COMPARISON OF BIODEGRADABLE INTERFERENCE SCREW ALONE AND COMBINATION OF INTERFERENCE SCREW AND ENDOBUTTON**

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### **Objectives:**

Compare graft elongation, elastic deformation and strength of two techniques.

### **Methods:**

We used 12 pair of fresh human cadaver knees. Groups were paired and randomized r and l. Hamstrings were harvested for a quadruple loop graft. Grafts were prepared, tensioned to 40N for 5 min, sized and kept moist. ACL reconstructions were performed arthroscopically. The ACL was identified, removed and notchplasty performed. Using an acufex guide at 55° the tibial tunnel was drilled to graft size. The ACL insertion in the notch was identified and a pin was placed.

Group 1 - 12 endobutton(EB)/biodegradable interference screw(BIS) fixations. A 4.5 mm bit was placed over the femoral guide pin and drilled through the cortex. Tunnel length was measured to determine EB and graft length in the tunnel. The graft portion was drilled to match graft size. The graft was marked at tunnel length and TL+10mm. EB and graft were pulled through the tunnel to the TL+10mm mark. The EB was toggled, then the graft pulled until the EB was against the cortex. A BIS, oversized by 1mm was placed. Gentle traction was pulled to prevent drawing graft into the tunnel.

Group 2 - 12 BIS fixations. Femoral tunnel was drilled to graft size. The tendon was pulled 25mm into the tunnel and a 1mm oversized BIS placed.

Testing: Soft tissues were removed. Graft ends were secured in a custom clamp leaving 25mm of graft exposed. Femurs were mounted on a servohydraulic test frame. Grafts were preloaded at 40N then cycled 100 times between 40N and 100N, 200N, 300N, and 1000 times at 400N. Force was pulled in line with the tunnel. If no failure occurred grafts were strained at 100mm/sec.

### **Results:**

EB/BIS average pullout strength =  $1071 \pm 381$ N, BIS =  $515 \pm 280$ N.  $P = .001$  by paired t-test. Elastic deformation and elongation were not significantly different. Bone Density for EB/BIS =  $.544 \pm .190$ g/cm<sup>3</sup> and BIS =  $.5635 \pm .2635$ g/cm<sup>3</sup>. Three pairs were excluded due to posterior cortex violation, tied EB, and MTS failure.

### **Conclusions:**

EB/BIS is significantly stronger. BIS had 6/9 failures &le;400N with slippage past the screw during cycling. As expected deformation and elongation were not significantly different. Further research into endobutton fixation is demonstrating significant elastic deformation during cycling. This double fixation technique, EB/BIS, improves strength while minimizing elastic deformation and elongation.

## **LONG HEAD OF BICEPS BRACHII TENDON TENODESIS COMPARING THREE FIXATION METHODS: A BIOMECHANICAL STUDY**

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### **Objectives:**

The long head of the biceps tendon (LHB) may spontaneously rupture or may be arthroscopically released for anterior shoulder pain. When tenodesis is performed, rehabilitation is slowed in order to protect the repair. In our study we examined the load to failure and ability to withstand cyclic loading simulating active elbow range of motion with three different fixation procedures.

### **Methods:**

Six paired fresh frozen cadaveric shoulders were randomly assigned into 3 groups: Mitek anchors, Linvatec bioabsorbable interference screw, and soft tissue washer and screw. Four shoulders in each group underwent tenodesis according to standard surgical technique. Cyclic loading was applied in a sine wave configuration from 0 to 50 Newtons at 2 Hz for 1000 cycles. Load to failure was tested and at a ramp rate of 50 mm/min. DEXA scan was performed on all specimens.

### **Results:**

No specimen failed during cyclic testing. There was no statistical difference in load to failure between the bioabsorbable screw (82 +/- 17.45) and the soft tissue washer & screw (104.67 +/- 31.18), however, Mitek anchor fixation was significantly greater (152.50 +/- 14.48,  $p < 0.05$ ) than both groups. Failure in the Mitek anchor group occurred at the suture, whereas, failure occurred in the tendon at its interface with the fixation device in the two other groups. There was no failure at the bone fixation site. There was no difference between the DEXA scan of all specimens.

### **Conclusions:**

Cyclic loading results suggest that tenodesis utilizing all 3 fixation methods are sufficient to allow for immediate active range of motion of the elbow after surgery. Mitek suture anchors failed at significantly greater loads than the other two groups. Interference screw fixation and screw and washer fixation can potentially result in weakening of the tendon at its interface with the fixation device. None of the fixation devices failed at the bone site, suggesting that the presence of osteoporotic bone should not preclude one from tenodesing a biceps using one of these three fixation methods.

## **ADAPTIVE CHANGES IN BASEBALL PLAYERS: COMPARISON OF 300 AAU BASEBALL PLAYERS**

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### **Objectives:**

The purpose of our study was to determine whether differences in shoulder range of motion (ROM) and laxity of baseball players are the result of adaptive or congenital influences.

### **Methods:**

We studied 298 baseball players (range 8-28 y.o) from three age groups: Group 1 - 100 8-12 y.o, group 2 - 100 13-14 y.o, group 3 - 98 15-28 y.o. Players were excluded if a history of shoulder pathology existed. Players were supine to stabilize the scapula and goniometric measurements were taken in forward elevation (FE), external rotation in neutral (ERN), external rotation in 90° of abduction (ERAB), and internal rotation in 90° of abduction (IRAB). Active internal rotation (IRN) was recorded as the highest vertebral level reached. General ligamentous laxity (GLL) was graded by thumb hyperflexion, MCP hyperextension, and elbow recurvatum. The distance of humeral head translation determined inferior (IL) and anterior laxity (AL) grades.

### **Results:**

- (1) FE: There was no statistically significant side to side (sts) difference between any of the three groups.
- (2) ERN: Group 2 and group 3 had significantly greater sts difference than group 1 ( $P<0.05$ ).
- (3) ERAB: Group 2 and group 3 had a significantly greater sts difference than group 1 ( $P<0.05$ ). Group 3 had a significantly greater sts difference than group 2 ( $P<0.05$ ).
- (4) IRAB: Group 3 had a significantly greater sts difference than group 2 or group 1 ( $P<0.05$ ).
- (5) IRN: Group 3 had a significantly greater sts difference than group 2 or group 1 ( $P<0.05$ ).
- (6) GLL: Group 1 had significantly greater GLL than group 2 or group 3 ( $P<0.05$ ).
- (7) IL: Both group 2 and group 3 had significantly greater dominant IL than group 1 ( $P<0.05$ ).
- (8) AL: Both group 2 and group 3 had significantly greater dominant AL than group 1 ( $P<0.05$ ).

### **Conclusions:**

Group 1 had no significant sts differences in ROM and laxity. The largest differences in ROM and laxity were between group 1 and group 3. Group 1 had the greatest GLL, yet group 3 demonstrated the greatest sts difference in ROM and laxity. These results indicate that the changes observed in shoulder ROM and laxity are adaptive changes based on repetitive overhead throwing and not due to congenital factors.

## **BIOMECHANICAL ANALYSIS OF A POSTERIOR CAPSULAR CONTRACTURE OF THE SHOULDER**

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### **Objectives:**

Overhead athletes can develop numerous conditions that are often attributed to an underlying anterior capsular laxity. However, many of these athletes have an accompanying loss of internal rotation and posterior capsular tightness. A posterior contracture may be part of the underlying pathology in the symptomatic thrower's shoulder. We sought to evaluate the effect of a surgically created posterior capsule contracture using a passive and dynamic model of glenohumeral motion.

### **Methods:**

Eight fresh frozen cadaveric specimens were tested using a model capable of measuring glenohumeral rotations and translations during passive movements as well as during simulated, active muscle contraction. The posterior capsular contracture was created by performing a capsulotomy and advancing the capsule one centimeter medially. Active muscular loads were applied using hydraulic cylinders pulling in the line of action of each of muscles of the rotator cuff and three heads of the deltoid. Simulated muscle contraction produced an active abduction-external rotation motion similar to the cocking phase of the throwing motion. A power analysis ( $\beta=0.8$  and  $\alpha=0.05$ ) was performed using pilot data to determine the sample size of eight. Data were analyzed using Wilcoxon rank sum tests and linear regression modeling.

### **Results:**

Posterior capsular contracture resulted in significant reductions in maximal internal rotation and total rotation arc ( $p=0.001, 0.002$  respectively) at 0 degrees abduction. At 90 degrees of abduction, maximum internal rotation was decreased ( $p=0.004$ ). In the dynamic analysis, there was a significant decrease in active abduction ( $p=0.047$ ) using identical muscle forces. Extension and external rotation were both increased. ( $p=0.003, 0.004$ ) Coupled A-P translation was significantly displaced anteriorly by an average of 7mm. ( $p=0.008$ )

### **Conclusions:**

Application of a posterior capsular contracture significantly alters glenohumeral kinematics. It appears that many of these changes are similar to that previously attributed to anterior insufficiency. Attention to the posterior capsule may be necessary to improve treatment of the throwing athlete's shoulder.

## **RADIOGRAPHIC EVIDENCE OF ABNORMAL PATELLOFEMORAL POSITION IN PATIENTS WITH PATELLAR TENDONITIS**

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### **Objectives:**

Abnormal patellofemoral position has been identified as a contributing factor in several patellofemoral pathologies. Patellar tendonitis is an overuse injury attributed to excessive stress on the patellar tendon. The role of imaging studies in identifying patellar tendonitis remains controversial. The purpose of this study was to determine if patellar tendonitis was associated with abnormal patellofemoral position in the sagittal plane. A radiographic measurement called the A/P patellar tilt angle was defined as the angle created by a line drawn along the anterior cortex of the distal femoral diaphysis and a line drawn along the central longitudinal ridge of the articular surface of the patella.

### **Methods:**

Optimum radiographic position was determined using five cadaveric knees. Normative values and measurement reliability were established using 58 individuals with no history of knee pathology. Lateral radiographs were obtained on 77 patients (95 knees) with symptomatic anterior knee pain who met our inclusion criteria for one of 3 isolated pathologies of the patellofemoral joint: patellar tendonitis (19), patellofemoral pain syndrome (PFP) (42), or patients more than six months following bone-patellar tendon-bone autograft ACL reconstruction (16). All measurements were made by a single, blinded investigator. Reliability was assessed by Pearson product-moment correlation coefficients. A/P tilt patellar angles were compared using T-tests.

### **Results:**

Intratester measurements on normals exhibited high reliability (ICC=.97). The A/P tilt patellar angle for the patellar tendonitis group was  $25.6^{\circ} + 7.0^{\circ}$  which was significantly lower ( $p < 0.01$ ) than the normal population ( $30.8 + 6.7$ ). The mean A/P tilt angle for the PFP group ( $29.1^{\circ} + 8.5^{\circ}$ ) and the ACL reconstruction patients ( $35.5^{\circ} + 6.2$ ) was not different from the control population ( $p = 0.29$  and  $p = 0.19$ ).

### **Conclusions:**

Our study demonstrates that patients with patellar tendonitis have abnormal patellar position in the sagittal plane. In this group of patients the inferior pole of the patella was tilted anteriorly, away from the tibial tubercle. This difference in A/P tilt angle compared to controls may represent increased tension through the extensor mechanism resulting in enthesopathy.

## **ARTHROSCOPIC AUTOGENOUS OSTEOCHONDRAL GRAFT FIXATION (MOSAICPLASTY) OF UNSTABLE OSTEOCHONDRITIS DISSECANS LESIONS OF THE KNEE**

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### **Objectives:**

To assess the use of autogenous osteochondral graft fixation (mosaicplasty) in unstable osteochondritis dissecans (OCD) lesions (Clanton type 2 and 3) of the knee.

### **Methods:**

Twelve patients with x-ray and MRI confirmed OCD lesion in their femoral condyle, that had remained symptomatic despite adequate conservative treatment (average 3yrs (range 1-6yrs)), underwent arthroscopic mosaicplasty plug fixation of the lesion. The OCD lesions were all loose at operation and were all fixed rigidly in situ using a number of autogenous 4.5mm osteochondral plugs harvested from the edge of the trochlear groove. The average age at operation was 17.2 years (14 - 27yrs). The patients were prospectively assessed both clinically and by MRI scan at 3, 6 and 12 months and then six monthly. Average follow up was 2.4 years (2 - 4.1).

### **Results:**

Prior to operation all patients had joint effusions and were experiencing pain limiting their activities. By 6 months post-operation the IKDC score had returned to normal in all cases, none of the patients had joint effusions or pain and all had a full return of muscle strength. Serial MRI scans documented healing of the osteochondral plugs and a continuous articular cartilage surface layer in all cases by 9 months.

### **Conclusions:**

Using mosaicplasty plug fixation we were able to obtain healing in all 11 unstable OCD lesions. The benefits of this technique are the ability to obtain rigid stabilization of the fragment using multiple plugs, stimulation of the subchondral blood supply by drilling and autogenous cancellous bone grafting.

Conclusion: We conclude that mosaicplasty plug fixation of unstable OCD lesions in the knee is a good technique and recommend its use.

## **THE EFFECTIVENESS OF A PRESEASON EXERCISE PROGRAM ON THE PREVENTION OF GROIN STRAINS IN PROFESSIONAL ICE HOCKEY PLAYERS**

*Timothy Tyler, PT/ATC (New York, ), Richard Campbell, MS, ATC (Uniondale, ), Stephen Nicholas, MD (New York, ), Sean Donellan, ATC (Uniondale, NY), Malachy McHugh, PhD (New York, )*

### **Objectives:**

A structured plan for injury prevention requires (1) documenting injury incidence; (2) identifying specific risk factors; (3) implementing an intervention; and (4) evaluating the effectiveness of the intervention. Groin strains are among the most common injuries in ice hockey. The authors previously demonstrated an incidence of 3.2 groin strains per 1,000 player-game exposures in professional ice hockey players. Hip adductor weakness was identified as a strong risk factor (Tyler TF et al. AJSM 29(2), 2001). The purpose of this study was to prospectively test the effectiveness of an intervention program in reducing the incidence of groin strains in professional ice hockey players.

### **Methods:**

Based on preseason hip adductor strength, 23 of 41 players from the same NHL team were identified as "at risk" and were placed in an intervention program. The program consisted of therapeutic strengthening exercises that were performed three times a week for 6 weeks. Injury and individual exposure data were recorded on all players for the subsequent season. An injury was defined as any event that kept a player out of a practice, game, or required the attention of the team physician. A groin strain was defined as a strain of the adductor muscle group. Injury incidence was compared to the incidence in the two seasons prior to the intervention season.

### **Results:**

There was one groin strain in the season subsequent to the intervention, compared to 11 in the previous two seasons (0.47 vs. 3.2 per 1000 player game exposures,  $p=0.06$ ). The injury was a grade I strain and occurred in preseason. The groin strain resulted in one missed game compared to 27 missed games, due to groin strains in the previous seasons (0.5 vs. 7.9 per 1000 player game exposures,  $p=0.003$ ). This player was not in the intervention group. The incidence of all injuries was similar to the previous two years (15.1 vs. 17 injuries per 1000 exposures).

### **Conclusions:**

A therapeutic intervention of strengthening the adductor muscle group appears to be an effective method for preventing groin strains in professional ice hockey players. By documenting injury incidence and identifying a specific risk factor we were able to design, implement, and document an intervention to demonstrate a decreased incidence of groin strains in NHL players.

## **CLINICAL RESULTS OF AUTOLOGOUS CHONDROCYTE IMPLANTATION FOR LARGE FULL-THICKNESS CHONDRAL DEFECTS OF THE KNEE: FIVE YEAR EXPERIENCE WITH 112 CONSECUTIVE PATIENTS.**

*Scott Gillogly, MD (Atlanta, GA),*

### **Objectives:**

Treatment of large full thickness chondral defects of the knee by traditional methods of debridement, chondroplasty or marrow stimulation techniques have demonstrated less than satisfactory results. Since 1995, autologous chondrocyte implantation (ACI) became available for treating large full thickness chondral lesions of the knee. ACI produces a hyaline-like repair tissue. This clinical series evaluates the efficacy, durability and clinical results of this repair technique over a 5 year period.

### **Methods:**

112 patients with 139 defects, (average size 5.7 cm squared), were treated with ACI between July 1995 to December 2000. This included 96 condyle defects, 27 trochlea defects, 15 patellar defects, and 1 lateral tibia. 22 of the 112 patients had multiple defects. Over 60% of patients had failed at least one prior treatment. Patients were followed at regular intervals and their progress monitored using the Modified Cincinnati Rating Scale (clinician and patient), Sports Score and Knee Society Rating Scale. Of 56 patients with greater than 24 month follow-up, 3 have been considered failures and 3 have been lost to follow-up. The remaining 50 have an average follow-up of 43 months in a range of 24-65 months.

### **Results:**

There was a statistically significant improvement in all scores between baseline and 1 year following implantation and between 1 year and 2 years following ACI. At greater than 2 year follow-up, the Modified Cincinnati Rating Scale shows 93% having good to excellent outcomes by clinician evaluation and 89% good to excellent outcomes by patient evaluation. There was no deterioration in results between two and five year follow-up.

### **Conclusions:**

ACI is an effective and durable repair technique for patients with large chondral lesions of the knee. The long-term data demonstrated that patients were able to return to active, productive lifestyles with no decrease in functional outcomes with longer follow-up.

## **THE EFFECTS OF RADIOFREQUENCY TREATMENT ON CHONDROCYTES AND ARTICULAR CARTILAGE MATRIX OF FIBRILLATED CARTILAGE**

*Anne Ryan, MD (Columbus, OH), Alicia Bertone, DVM, PhD (Columbus, OH), Christopher D. Kaeding, MD (Columbus, OH), Kris Backstrom, BS (Columbus, OH), Steve Weisbrode, DVM, PhD (Columbus, OH)*

### **Objectives:**

The purpose of this study was to determine if commercially available radiofrequency (RF) probes used in arthroscopic surgery have detrimental effects on articular cartilage chondrocytes. Chondrocyte well being was determined by proteoglycan metabolism, cell viability and tissue morphologic changes associated with 3 different energy settings and a control.

### **Methods:**

Cartilage explants were developed from 11 horses (ages 2 weeks to 20 years). Horse patellas were harvested and divided into thirds. Patellar fibrillation was created with a rasp to mimic clinical fibrillation. One patella served as a fibrillated articular cartilage control. Treated patellae were treated in each third with one of 3 different energy settings (20, 40, or 60 watts) for 4 minutes in a paintbrush pattern under arthroscopic guidance. Cartilage explants (in duplicate) were incubated for 24 hours at 37 degrees Celsius and 95% humidity. Proteoglycan synthesis (Na<sup>35</sup>SO<sub>4</sub> incorporation for 24 hours), proteoglycan degradation (Na<sup>35</sup>SO<sub>4</sub> release for 72 hours) and cell viability (Trypan blue stain) were measured. Histomorphometric analysis of cartilage was performed and cytologic and matrix characteristics were examined. Quantitative data were analyzed with a 2-way ANOVA to compare results among temperature settings and between groups.

### **Results:**

Significant results ( $p < 0.05$ ) were obtained from the proteoglycan synthesis, degradation and viability data. RF applications at all 3 settings significantly decreased proteoglycan synthesis of the chondrocytes. Increasing RF energy setting decreased proteoglycan synthesis among treatment groups. Proteoglycan degradation increased with increased temperature setting. RF settings of 40 and 60 Watts had significantly greater degradation than the 20 Watt treatment group or controls. Increasing energy corresponded to decreased cell viability in higher energy groups. Control cartilage cultured for 7 days had 89% viability. RF treatment at 40 and 60 Watts decreased viability to 81% ( $p = 0.59$ ) and 73% ( $p = 0.001$ ) respectively.

### **Conclusions:**

Our results showed that RF treatment of cartilage has immediate detrimental effects on chondrocyte metabolism. Cell viability and proteoglycan synthesis decreased and proteoglycan degradation increased with increased power settings. Based on our study cautious use of RF energy treatment of cartilage is recommended until studies evaluate more long term in vivo effects of RF energy treatment of cartilage.

## **AN ANATOMIC RECONSTRUCTION OF THE POSTEROLATERAL CORNER: A BIOMECHANICAL STUDY**

*Robert LaPrade, MD (Minneapolis, ), Steinar Johansen, MD (Oslo, Norway), Lars Engebresten, MD/PhD (Oslo, Norway), Andy Tso, (Minneapolis, MN), Fred Wentorf, MS (Minneapolis, )*

### **Objectives:**

To date, no surgical method for posterolateral knee instability anatomically reconstructs the three major stabilizing structures of the posterolateral knee: the fibular collateral ligament (FCL), the popliteus tendon (PLT), and the popliteofibular ligament (PFL). In this study, a novel technique which reconstructs the anatomy of these structures was demonstrated and tested in vitro. The primary hypothesis was that static varus stability will be restored to the reconstructed knee. A secondary hypothesis was that the relative loading forces will be restored in the reconstructed ligaments.

### **Methods:**

The anatomic locations of the original FCL, PLT, and PFL were replicated using a two graft technique. Ten paired cadaveric specimens were tested by applying loads in varus and external rotation three times at 0°, 30°, 60°, and 90° of flexion. Each specimen was tested in three states: intact knee; knee with the FCL, PLT, and PFL cut to simulate a grade III injury; and reconstructed knee. The primary hypothesis was tested using motion analysis data. The secondary hypothesis was tested using force data obtained from buckle transducers placed on the FCL and the PFL in the intact knee, and on the FCL and PLT grafts in the reconstructed knee.

### **Results:**

For the varus loading tests, a significant increase in translation occurred between the intact knee and the cut posterolateral structures knee ( $p < .01$ ). Joint stability was restored by the posterolateral reconstruction ( $p < .02$ ), which was not different from the intact knee stability.

The load response of a given ligament was obtained from the buckle transducer data at each flexion angle. The average varus load response of the intact FCL was significantly higher than that of the intact PFL ( $p < 0.01$ ) and the reconstructed FCL ( $p < 0.05$ ) at 30°, 60°, and 90°. There was, however, no significant difference at any flexion angle between the average varus load responses of the reconstructed FCL and the reconstructed PLT (Table I).

### **Conclusions:**

This work demonstrated and tested a novel two graft reconstruction of the primary static stabilizers of the posterolateral knee: the FCL, PLT, and PFL. This technique restored static varus stability, as measured by joint translation in response to varus loading, to knees with grade III posterolateral injuries at most flexion angles. This procedure also significantly reduced the FCL varus load-bearing capacity in the reconstructed knee, to the point where it is indistinguishable from the varus load-bearing capacity of the reconstructed PLT.

## **THE PARTIAL THICKNESS ROTATOR CUFF TEAR: IS ACROMIOPLASTY WITHOUT REPAIR SUFFICIENT?**

*Frank Cordasco, MD (New York, NY), Marianne Backer, MD (Glostrup, ), Edward Craig, MD (New York, NY), Dana Klein, (New York, NY), Russell Warren, MD (New York, NY)*

### **Objectives:**

The purpose of this study is to evaluate the clinical outcome of arthroscopic acromioplasty and debridement in patients with Grade 1 (frayed tendon) and 2 (those comprising less than 50% of the tendon substance) partial rotator cuff tears (Ellman & Gartsman). The L'Insalata self-assessment questionnaire was used as an outcome instrument and to determine if the results are less satisfactory in this group as compared to a group of patients with impingement in the absence of a partial tear.

### **Methods:**

One hundred five patients with 107 shoulders (65%) were evaluated. Mean follow-up was 52.7 months (4.5 years) with a range of 2 to 10 years. There were three groups within the study population. Bursal side tears comprised 18% (14/77) of all partial tears.

### **Results:**

Group A consisted of 29 patients (30 shoulders) with impingement and no identifiable tear: 19 men and 10 women with a mean age of 48 years (range 24 – 76 years). The mean L'Insalata score was 91, with a range of 30 – 100. Group B comprised 25 patients with Grade 1 partial thickness rotator cuff tears: 15 men and 10 women with a mean age of 57 years (range 36 - 90 years). The mean L'Insalata score was 89, with a range of 40.5 – 100. The largest subgroup, Group C included 51 patients (52 shoulders) with Grade 2 partial thickness rotator cuff tears: 32 men and 19 women with a mean age of 53 years (range 33 – 72 years). The mean L'Insalata score was 89, with a range of 35 – 100. Overall, eight patients (8%) scored less than 70 points (range 30-65.5) on the L'Insalata scale and all failed early on. Of these 8 patients 4 had bursal side partial tears. The patients with Grade 2B (bursal) partial tears had a significantly higher failure rate (38%).

### **Conclusions:**

This study confirms the efficacy of arthroscopic subacromial decompression as a reliable and consistent treatment for subacromial impingement syndrome and rotator cuff disease, as evidenced by a mean L'Insalata score of 90 for all study groups. While the clinical outcome in patients with partial thickness tears of the rotator cuff comprising less than 50% of the tendon (Grade 1 & 2) is not significantly different than in patients without partial cuff tears, the subgroup of patients with Grade 2B partial tears had a significantly higher failure rate (38%) and may be better served with primary repair. Finally, with follow-up in this series out to 10 years in a number of patients, there is no evidence to suggest that clinically relevant or symptomatic intrinsic rotator cuff pathology progresses in those patients with partial thickness tears.

## **BRIEF COMPUTERIZED COGNITIVE TEST BATTERY YIELDS OBJECTIVE EVIDENCE TO INFORM CONCUSSION GUIDELINE DEVELOPMENT**

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### **Objectives:**

Existing sports concussion guidelines were developed largely by clinical judgment and are not yet fully linked to objective evidence of deficits that persist after injury. We hypothesized that a brief onsite computerized screen of cognitive function could aid assessment of immediate deficits and the recovery process.

### **Methods:**

438 U.S. Military Academy (USMA) cadets received computerized neuropsychological testing prior to starting a physical education boxing program. Certified athletic trainers retested concussed students within 1 hour of injury and again 4 days later at the time of return to full activity. The established concussion management system at USMA requires a 4 day pass from contact sports for all cadets experiencing concussion, including cadets with no physical symptoms after concussion. If symptoms do not improve over 20 minutes, additional medical evaluation is completed and the pass is extended. Two-tailed t-tests were used to compare follow-up and baseline scores of the concussed group.

### **Results:**

Fourteen cadets experienced a mild concussion without loss of consciousness or amnesia and reported no physical symptoms upon return to normal activity 4 days later. Using AAN concussion guidelines, 8 cadets experienced Grade 2 concussion, the other 6 were Grade 1. All cadets were classified as Grade 1 by Colorado guidelines. All cadets showed slowed reaction time immediately and 4 days after injury on the Continuous Performance and Simple Reaction Time tests. Tests involving more complex cognitive functions showed no significant change after concussion.

### **Conclusions:**

In mild sports concussion, tests of basic attention are more sensitive to concussion than tests requiring complex mental processing. Although all cadets were asymptomatic and had returned to normal activity on day 4, they still had slowed reaction time. Brief computerized cognitive tests such as ANAM, when combined with the computer classrooms available at many schools, make it possible to baseline large numbers of athletes rapidly and inexpensively. The large scale use of this technology to establish within-subject baselines should enable the collection of scientific evidence that will contribute to the formulation of more objective return-to-play guidelines.

## **GENDER DIFFERENCES IN KINEMATICS AND EMG ACTIVITY IN THE SINGLE LEG SQUAT**

*Brian Zeller, MS, ATC (Winona, MN), Jean McCrory, PhD (Lexington, KY), W. Kibler, MD (Lexington, KY), Timothy Uhl, PhD/PT (Lexington, KY)*

### **Objectives:**

This study evaluated the trunk, pelvic region, hip, knee and ankle kinematics of normal athletes while performing a single leg squat. Three-dimensional kinematic evaluation (60 Hz) of each joint was performed comparing males to females. Electromyographic (EMG) activity of eight selected muscles were also analyzed (960 Hz) and compared between males and females.

### **Methods:**

18 intercollegiate athletes (9 male, 9 female) from a local NAIA college volunteered for this study. Subjects were free from any lower extremity surgery or current injury. Subjects were instrumented with surface EMG electrodes over the dominant leg's rectus femoris, vastus lateralis, medial gastrocnemius, biceps femoris, gluteus maximus, gluteus medius, rectus abdominis and erector spinae. Maximal voluntary isometric contractions (MVIC) for each muscle were collected. Subjects were then instrumented with reflective markers for kinematic evaluation. Subjects performed five single leg squats on their dominate extremity, lowering themselves as far as possible and then returning to a standing position without losing their balance.

### **Results:**

Using all the data points in a one-way ANOVA, significant differences were found between male and females in the following joint angles ( $p < .05$ ). Women demonstrated significantly more ankle dorsiflexion, ankle pronation, hip adduction, hip flexion, hip external rotation, and trunk lateral flexion than their male counterparts. Females also demonstrated a decreased ability in maintaining knee varus during the single leg squat than the male subjects. EMG data analyzed using all the muscles in a MANOVA found that females had a greater activation as compared to the males ( $p < .05$ ) as measured by the area under the linear envelope. When each muscle was analyzed separately the rectus femoris activation was found to be statistically greater in females ( $p < .05$ ).

### **Conclusions:**

The kinematic data reveal significant gender differences in position of all the joints in the leg under a closed chain load, similar to that experienced in sports. Females show decreased control of the hip and ankle in all planes and of the knee in the critical varus/valgus plane. Females also activate their quadriceps, a known contributor to increased ACL strain, at a higher level. These data suggest under a physiologic load in a position commonly assumed in sports, females tend to place their entire lower extremity and activate muscles in a manner that could increase strain on the ACL.

## **PROPRIOCEPTION IN MULTI-DIRECTIONAL INSTABILITY**

*Jay Adlington, BS (London, Ontario, ), Alexandra Kirkley, MD (London, ), Gillian Edmonds, MS (L-ondon, Ontario, ), Ian Lo, MD (Calgary, Alberta, ), Sharon Griffin, (London, Ontario, )*

### **Objectives:**

The role of proprioceptive deficit in MDI has been theorized but remains unproven. The purpose of this study was to determine if MDI shoulders demonstrate proprioceptive deficit compared to contralateral unaffected shoulders in the same individuals, and compared to control shoulders in healthy individuals.

### **Methods:**

Patients with MDI meeting specific inclusion/exclusion and control subjects(C) matched for age and gender, gave informed consent to participate. Proprioception was tested on the Cybex 6000 isokinetic dynamometer as threshold to detection of passive motion (TTDPM) and reproduction of passive positioning (RPP) for two starting positions: 30° and 60° of external rotation. The mean difference of angular displacement between affected and contralateral unaffected shoulders, and between affected and control shoulders were calculated. Sample size of 15/group was estimated to have 80% power to detect 10° difference with  $p = 0.05$ .

### **Results:**

15 subjects (11M, 4F) were recruited for each group. MDI shoulders demonstrated statistically significant mean proprioceptive deficit for TTDPM at both starting positions compared to controls. With the numbers available, only a trend was detected for RPP. No significant difference was found between affected (A) and (U) unaffected shoulders in unilateral MDI subjects.

### **Conclusions:**

Results indicate that sensation of joint movement is affected to a greater extent than sensation of actual joint position. Proprioceptive deficit can be demonstrated in MDI shoulders but alone does not account for symptoms of MDI as contralateral unaffected shoulders in the same individual demonstrate a similar deficit.

## **RANDOMIZED CLINICAL TRIAL ASSESSING THE EFFECTS OF GRAFT TENSIONING USING SEMITENDINOSUS AND GRACILIS TENDONS IN ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION**

*Elizabeth Dinevski, MS (London, ), Alexandra Kirkley, MD (London, ), Annunziato Amendola, MD, FRCSC (London, ), Robert Litchfield, MD (London, ), Peter J. Fowler, MD, FRCS (London, )*

### **Objectives:**

The aim of this study was to compare the effects of two different levels of graft tension applied during arthroscopic ACL reconstruction using an autogenous doubled semitendinosus and gracilis tendon graft.

### **Methods:**

It was a prospective, double-blinded, randomized clinical trial at one investigational site. Male and female candidates were randomized to receive either a high (3.5MPa) or low level (1.5MPa) of stress, with the knee in full extension when setting graft tension at time of tibial attachment. Stratification was by surgeon and time of injury (injury for >1 year to surgery or injury <1 year to surgery). Primary efficacy measure was side-to-side anterior tibial laxity as measured by the KT-1000. We are reporting on time 0, 3, 6 and 12 mos post-operative data of anterior tibial laxity. Subjects will also be reviewed at 18 and 24 mos after surgery.

### **Results:**

When comparing the high and low tension groups immediately after surgery, we find significant (Mann-Whitney;  $p=0.049$ ) values. The high stress group (25 subjects) had a mean side-to-side difference of  $-0.51 \pm 1.52$  mm and the low stress group (24 subjects) showed a mean of  $0.13 \pm 1.42$  mm when evaluated using the KT-1000 knee arthrometer. Results at 3, 6 and 12 months indicate that there is not a statistically significant difference between the groups. However when comparing the change over time, there was a statistically significant difference for side- to side translation between the groups. The high stress group actually demonstrated more graft elongation than the low stress )group.

### **Conclusions:**

Results demonstrate patients with low graft tension regain knee stability at a measure closer to their uninjured knee at the immediate post-operative measure. Results over time indicate that both groups show graft lengthening over the first 12 months and high stress results in more elongation when compared to low stress. These early results indicate that graphs should be fixed under low stress at the time of ACL reconstruction.

## **DYNAMIC EVALUATION OF CONTACT PRESSURE AND EFFECT OF GRAFT HARVEST AT OSTEOCHONDRAL DONOR SITE IN THE KNEE**

*Joseph Guettler, MD (Royal Oak, MI), Kenneth Jurist, MD (Royal Oak, MI), Constantine K. Demetropoulos MS, King Yang, PhD (Detroit, MI)*

### **Objectives:**

Donor site morbidity is a consideration in osteochondral autografting about the knee. The recommended donor sites are presumed to be nonweightbearing or nonarticulating, however, it has been recently shown that these areas may indeed be subjected to contact pressures. One such area is the periphery of the lateral femoral condyle above the sulcus terminalis. The objectives of this study were to 1) Dynamically evaluate contact pressures about the periphery of the lateral femoral condyle where osteochondral plugs are commonly taken, 2) Determine whether small defects created in this area significantly alter rim contact stress on the surrounding cartilage, and 3) Determine the effect of lateral release on these pressures.

### **Methods:**

Digital electronic pressure-sensing cells were placed about the periphery of the lateral femoral condyle in ten fresh-frozen cadaveric specimens. Nonweightbearing resistive extension was simulated as the knees were placed through a functional range of motion. Dynamic pressure readings were recorded throughout the arc of motion. Measurements were first taken over intact cartilage. Rim contact stress was then evaluated about small 5 mm defects created in this area. Finally, the effect of lateral release on these pressures was evaluated.

### **Results:**

The pressure cells were all subjected to contact pressures throughout segments of the functional arc of motion. However, the creation of small osteochondral defects did not lead to a significant increase in rim stress concentration over the surrounding cartilage. The addition of a lateral release did not significantly alter the pressures.

### **Conclusions:**

Although the cartilage about the periphery of the lateral femoral condyle can be presumed to be articulating, our model suggests that sufficient patello-femoral contact pressure does not exist to significantly alter rim contact stress around small osteochondral donor defects in this area, with or without lateral release. This may have important implications related to the long-term integrity of the cartilage in this area following graft harvest.

## **WRIST FRACTURES IN GUARDED VS. NON-GUARDED SNOWBOARDERS**

*Daniel F. O'Neill, MD (Plymouth, NH), Mark McGlone, ATC (Plymouth, NH)*

### **Objectives:**

Assessment of the protective value of an "off the shelf" wrist guard originally designed for roller blading in preventing wrist fractures in first-time snowboarders.

### **Methods:**

Participants:

Two thousand three hundred and fifty-five first time snowboarders from one Northeastern ski resort.

Procedure: Five hundred and fifty-one of the first time snowboarders were randomly selected to wear wrist guards. A control group of eighteen hundred fist time snowboarders did not wear wrist guards. Wrist fractures in both groups were then assessed.

### **Results:**

In the non-guarded control group sixty-four wrist fractures were sustained (3.5%) compared to none (0%) in the guarded group ( $p < .01$ )

### **Conclusions:**

We conclude that firm plastic wrist guards are effective in preventing wrist fractures in first-time snowboarders, more importantly there was no increase seen in more proximal or distal upper extremity injuries in this guarded group.

## **DYNAMIC PERFORMANCE MEASURES AND STATIC CLINICAL MEASURES IN PREDICTING BALL VELOCITY IN PROFESSIONAL BASEBALL PITCHERS**

*Mark A. Curzan, MD , Tim Cook MS, Michael J. Decker MS, Michelle B. Sabick PhD, Michael R. Torry PhD, Richard J. Hawkins MD(Vail, CO)*

### **Objectives:**

The purpose of this study was to investigate dynamic performance based and static clinically based parameters that predict professional baseball pitch velocity.

### **Methods:**

The first part of study utilized three 120-Hz cameras to film forty major league professional baseball pitchers during a game situation. Full-body kinematic and kinetic measures were calculated by manually digitizing twenty body landmarks for each pitcher over a complete pitch cycle. Predictors of ball velocity were investigated with forward stepwise multiple regression. In the second part of the study, static shoulder and elbow ROM measurements were recorded in a second cohort (N=17) of professional pitchers. Forward stepwise multiple regression was used to predict fastball pitch velocity.

### **Results:**

Average pitch velocity was 90.9 mph ( $\pm 3.6$ ) across all pitchers. Analysis of the dynamic variables revealed six parameters that accounted for 37% of the variance in ball velocity. The four parameters that positively correlated with ball velocity were; maximal elbow angular velocity, maximal shoulder internal rotation angular velocity, time from stride foot contact to maximal shoulder external rotation, and time from maximal shoulder external rotation to ball release. The two parameters that negatively correlated with ball velocity were deviation from ideal stride length and maximal horizontal adduction force. Analysis of the eight static measures accounted for 54% of the variance in ball velocity. Of these, maximal shoulder external rotation at 90 degrees of shoulder abduction accounted for 40% of the variance in ball velocity.

### **Conclusions:**

Our study identified specific dynamic and static parameters that are predictive of ball velocity. The single best predictor, from both dynamic and static parameters, was the measure of maximal shoulder external rotation at 90 degrees of shoulder abduction. The pitchers ability to maximize shoulder external rotation enables them to pitch with increased velocity. Our previous studies have shown that this shoulder position leads to increased anterior shoulder stresses and potential shoulder injury.

## **TEMPORAL OUTCOMES OF ARTHROSCOPIC STABILISATION OF SUPERIOR LABRAL (SLAP) TEARS WITH BIODEGRADABLE TAC**

*Anastasios Paxinos, MD (Sydney, ), Judie Walton, PhD (Sydney, ), Sjoerd Rutten, MS (Sydney, ), George Murrell, MD/PhD (Sydney, )*

### **Objectives:**

The introduction of biodegradable devices has facilitated arthroscopic reattachment of labral tears. However the outcomes of reattachment of superior labral tears with these devices have not been reported. The aim of this study was to determine the temporal outcomes of arthroscopic stabilisation of superior labral tears.

### **Methods:**

The study was based on 20 patients with arthroscopically confirmed superior labral tears who completed a questionnaire regarding their shoulder pain and function and had a systematic assessment consisting of 27 shoulder tests prior to surgery. At the time of arthroscopy, the morphology of the labrum was recorded and the detached labra reattached with 1 to 3 (mean 1.6), Suretac anchors (Smith + Nephew, USA). The same assessments were made at 2 and 6 weeks, 3, 6, 12 and 24 months post-operatively. Data were analysed using ANOVA, t-tests and non-parametric tests with adjustments for multiple comparisons. The significance levels were set at  $p < 0.05$  and 0.8 power. For table: mean (SEM), \* =  $p < 0.05$ , \*\* =  $p < 0.01$ , \*\*\* =  $p < 0.001$  compared with pre-op surgery using Wilcoxon signed rank tests.

### **Results:**

There were no intra- or post-operative complications. Following labral reattachment there were decreases in shoulder pain scores, at rest (45%), at night (50%) and with activity (73%), with the most significant reductions occurring between 4 and 12 weeks ( $p < 0.001$ ). Patient-perceived weakness, instability and stiffness scores also improved from week 4. The overall problem ranking reduced from severe to mild at three months and remained so at two years ( $p < 0.001$ ). Patients' activity returned to pre-injury levels at six months. All ranges of motion were restored to pre-operative levels by three months. Strength, as assessed by manual muscle tests was normal throughout. Pre-operatively, 13/20 patients had a positive O'Brien sign: this sign was negative at all post-operative visits.

### **Conclusions:**

Arthroscopically delivered biodegradable tacs were an effective means to restore the disrupted anatomy of superior labral tears and resulted in near complete recovery of pain and function at 3 months. These good outcomes were still present at 2 years follow-up.

## EFFECTS OF INCREASING TIBIAL SLOPE ON THE BIOMECHANICS OF THE KNEE

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### **Objectives:**

High tibial osteotomy is commonly performed to treat lower extremity malalignment (coronal plane). However, inadvertent changes in the tibial slope (sagittal plane) may occur during the procedure, even in the hands of experienced knee surgeons. The effect of this alteration on knee biomechanics is not well understood. The objective of this study was to evaluate the effects of increasing tibial slope on knee kinematics and in situ forces in the cruciate ligaments. We hypothesized that increasing tibial slope would increase anterior tibial translation and in situ force in the ACL while decreasing posterior tibial translation and in situ force in the PCL.

### **Methods:**

Ten human cadaveric knees were tested using a robotic/ universal force moment sensor system. A 134N AP load and a 200N axial load were applied at 5 flexion angles and the resulting knee kinematics were determined. A 5 mm anterior opening wedge osteotomy was then created and rigidly fixed with a Puudu plate. Testing was repeated and the resulting kinematics recorded. The cruciates were individually transected and their in situ forces determined.

### **Results:**

Tibial slope increased from  $8.8 \pm 1.8^\circ$  to  $13.2 \pm 2.1^\circ$  after osteotomy. This caused an anterior shift in the resting position of the tibia relative to the femur, ranging from  $3.6 \pm 1.4$  mm at  $30^\circ$  to  $2.3 \pm 1.9$  at  $120^\circ$ . Under axial load, the osteotomy caused a significant relative anterior tibial translation compared to the intact knee of  $2.0 \pm 2.2$  mm and  $1.9 \pm 2.5$  mm at  $30^\circ$  and  $90^\circ$ , respectively ( $p < 0.05$ ). Under the AP load, no difference could be detected in total AP translation or the in situ forces in the cruciate ligaments between the intact and osteotomy conditions ( $p > 0.05$ ).

### **Conclusions:**

Increasing tibial slope caused an anterior shift in the resting position of the tibia relative to the femur that was accentuated under axial load. Thus osteotomies performed specifically to increase tibial slope could be beneficial in the treatment of the PCL deficient knee (i.e., reducing posterior tibial sag) and detrimental to the ACL deficient knee. Although tibiofemoral contact was altered, the in situ forces in the cruciates and overall knee laxity did not change significantly. This finding was contrary to our hypothesis and may be related to a change in the relative position of the cruciate insertions, or the increase in tibial slope may have been insufficient to elicit changes. Further study is needed to delineate the full implications of altering tibial slope on joint contact pressures and the biomechanics of ligament-deficient knees.

## **THERMAL CAPSULORRHAPHY FOR THE TREATMENT OF MULTI-DIRECTIONAL INSTABILITY OF THE SHOULDER**

*Anthony Miniaci MD, FRCSC (Toronto, ), Julie McBirnie MD, FRCS (Edinburgh, Scotland, ), Sara Lyn Miniaci, (Toronto, )*

### **Objectives:**

The objective of this study was to perform a prospective evaluation of thermal capsulorrhaphy for the treatment of multi-directional instability of the shoulder.

### **Methods:**

Multidirectional laxity of the shoulder should theoretically have the best possibility of surgical success with thermal capsulorrhaphy. The purpose of this study was to present the prospective evaluation of 19 patients with instability of the shoulder related to multi-directional laxity treated with thermal capsulorrhaphy (Oratec). Over two years, 19 patients with multidirectional instability were treated with thermal shrinkage. Fifteen patients had involuntary dislocation and four voluntary. Predominant direction of instability was anterior/ inferior in 10, posterior in 5 and multiple directions in 4. Patients were followed for a minimum of two years or until surgical failure recurrence of symptomatology. Patients were treated with thermal capsulorrhaphy, and maintained in sling immobilization for a period of 3 weeks post-operatively. At that time patients were reviewed regularly at 6 weeks, and 3, 6, 9 and 12 months and then at six month intervals. The Western Ontario Shoulder Instability Index was used as a clinical outcome measure as well as subjective and objective evaluation of patient's function, range of motion, pain and instability.

### **Results:**

Nine patients had recurrence of their instability occurring at an average of nine months following surgery (7-14 months). One patient had axillary nerve dysfunction. Three patients had additional sensory dysesthesias related to the axillary nerve territory. All neurological subjective evaluations recovered within 9 months. All the patients with predominantly posterior instability failed this surgical procedure. Only 2 of 10 (20%) with anterior instability had failed their operative procedure. Surgical revision has been performed in 5 of the 9 failures.

### **Conclusions:**

Analysis of patients with multidirectional laxity determined that thermal capsulorrhaphy had a significant failure rate with associated post-operative complications. Specifically those patients with a predominantly posterior component of instability had no surgical success with this procedure. We have abandoned this type of approach in patients with multi-directional laxity especially in those with posterior instability.

Conclusion: This new operative procedure met with a high failure rate, (9/19, 47%) with significant post-operative complications including axillary nerve dysesthesias and stiffness.

## **IDENTIFICATION OF THE CELLS THAT PARTICIPATE IN EARLY TENDON-TO-BONE HEALING**

*Hyon Jeong Kim, MD (New York, NY), Scott Rodeo, MD (New York, NY)*

### **Objectives:**

This study was performed to identify the phenotype of the cells that proliferate during early tendon-bone healing, and to identify the spatial and temporal localization of these cells.

### **Methods:**

Forty skeletally-mature, male New Zealand White rabbits were used. The semitendinosus tendon was transplanted into the knee joint as an ACL graft. Animals were given bromodeoxyuridine (BrDU) by intravenous injection and sacrificed at serial time points: 3 days, 1 week, 2 weeks, 3 weeks, and 4 weeks after surgery. Immunohistochemistry with various cell-specific markers was performed. Antibodies to BrDU, a marker for proliferating cells, CD45 (leukocyte common antigen, expressed in all hematopoietic cells), CD68 (a marker of monocyte/macrophage lineage cells), bone sialoprotein (BSP) and osteocalcin (bone matrix proteins expressed in osteoblasts) were used. Enzyme histochemistry was used to localize alkaline phosphatase using frozen sections prepared without decalcification.

### **Results:**

Positive BrDU staining indicating proliferating cells was seen in the periphery of the interface at 3 days after surgery. The number of BrDU-positive cells increased with time until 3 weeks, infiltrating into the tendon graft, then the proportion of positive gradually decreased by 4 weeks. CD45-positive cells were seen in the interface at the early time points and actively grew into the tendon graft with time; however, at 4 weeks positive cells remained only in the periphery of the interface. The CD68-positive cells were also seen among both the interface cells and cells growing into the graft. Positive staining for BSP and osteocalcin was seen in the cells in the interface starting at 3 days and became more definite in both the interface cells and the cells growing into the tendon. By 4 weeks positive staining was seen only in the cells in some areas of the outer portion of the interface. Alkaline phosphatase activity was detected at the interface area between the tendon graft and the mineralized trabeculae.

### **Conclusions:**

The actively proliferating cells at the tendon-bone interface appeared to derive from the surrounding marrow cavity and may be participating in cellular repopulation of the tendon graft. These cells expressed various phenotypic markers: CD45, CD68, osteocalcin, and BSP. Early bone forming activity was detected at the tendon-bone interface and appears to play an important role in tendon-to-bone healing.

## **TIBIAL PLATEAU FRACTURES IN SKIERS AND SNOWBOARDERS**

*Peter Millett, MD (Vail, CO), Andrew Pennock, BS (Vail, CO), William Sterett, MD (Vail, CO)*

### **Objectives:**

There have been several new developments in ski technology in the past decade, including the introduction of parabolic skis and snowboards. We noticed that tibial plateau fractures were occurring more frequently. Therefore, the purpose of this study was to study the incidence, pattern, and associated injuries in skiers and snowboarders.

### **Methods:**

A retrospective review of 110 consecutive tibial plateau fractures during a single ski season (1998/99) was performed. The incidence, patterns, and mechanisms of injury were determined. Fractures were classified according to the Schatzker and AO/ASIF schemes. Body mass index, skier ability, terrain, and time of day were obtained from hospital and ski patrol accident reports.

### **Results:**

The incidence of tibial plateau fractures was 4.7 per 100,000 skier days. Skiers were 9.6 times more likely to sustain a tibial plateau fracture than snowboarders. Schatzker type II (34%) and III (34%) were the most prevalent patterns, followed by type VI (19%), type I (6%), type IV (4%), and type V (3%). Schatzker type I, II, and III were two times more common in women. Lower energy fractures (Schatzker I, II, III) occurred mainly in twisting falls, while higher energy Schatzker type V and VI were more common in collisions.

Tibial plateau fractures occurred most commonly in middle-aged adults (mean age 44) who were intermediate level skiers on intermediate level terrain with moderate snow conditions, such as hard-packed, soft-packed, or groomed snow. Bindings failed to release in 66% of the falls. A majority occurred in the late afternoon, potentially when snow conditions became more challenging and skiers became more fatigued. There was no correlation between body mass index and fracture severity. The most common associated injury was a lateral meniscal tear, which was present in 53% of all operatively treated fractures.

### **Conclusions:**

We found an incidence more than **FOUR TIMES** higher than previously reported. Skiers had almost a ten-fold increased risk over snowboarders. New ski technology, including the development of parabolic skis, has changed the velocity and radius of ski turns, potentially altering the nature of falls and injuries in alpine skiing. Better marketing data or differences in snow conditions are other explanations for the increase. In our series, the most common presentation was a middle-aged woman with a low velocity fracture of the lateral plateau sustained during a twisting fall. Higher energy fracture patterns were more common in younger skiers after a collision or direct impact.

## **THE EFFECT OF OPENING WEDGE HIGH TIBIAL OSTEOTOMY IN THE POSTERIOR CRUCIATE LIGAMENT (PCL) DEFICIENT KNEE**

*Douglas Naudie, MD (London, ), Sandie Roth, MSC (London, ), Cynthia Dunning, MSC(London, ), Annunziato Amendola, MD, FRCS (C) (London, ), James Johnson, PhD (London, )*

### **Objectives:**

To quantify the effect of opening wedge high tibial osteotomy on knee stability in the PCL deficient knee in vitro

### **Methods:**

Six fresh-frozen human cadaveric knee specimens with intact ligaments and menisci were mounted in a specialized knee testing apparatus. Freed quadriceps and hamstring tendons were secured to computer-actuated cables. Knees were tested unloaded at flexion angles of 15, 30, 45, 60, 75, and 90 degrees, and following application of static loads to simulate forces in the intact knee. Testing was first performed in the intact knee and sequentially following a 0mm, 5mm, and 10mm anterior opening wedge osteotomy. The PCL was then resected arthroscopically and testing was repeated sequentially following a 0mm, 5mm, and 10mm osteotomy. Changes in tibial slope and tibial translation were measured using an electromagnetic tracking device. Analysis of 3D knee movements was performed with the joint coordinate system described by Grood and Suntay (1983). The effects of tibial slope and PCL integrity on tibial translation at each flexion angle were analyzed using 2-way repeated measures ANOVA and Student-Newman-Keuls tests.

### **Results:**

Mean increase in tibial slope with 5mm opening wedge osteotomy was 7.5° (+/- 2.4°), and with 10mm osteotomy, 12.0° (+/- 3.1°). In the unloaded, PCL deficient knee, posterior tibial translation decreased at all flexion angles after 5mm and 10mm osteotomy. Statistical differences ( $p < 0.05$ ) were observed at flexion angles of 30°, 45°, 60°, and 75°. In the loaded, PCL deficient knee, posterior tibial translation similarly decreased at all flexion angles after 5mm and 10mm osteotomy. Statistical differences were observed only at flexion angles of 60° and 75°.

### **Conclusions:**

The results suggest that opening wedge osteotomy may decrease posterior tibial translation in the PCL deficient knee in vivo.

## HUMERAL HEAD RETROVERSION IN COMPETITIVE BASEBALL PLAYERS

*Chris Chant, BSc (London, ON, CANADA, ), Robert Litchfield, MD, FRCSC (London, ON, CANADA, ), Lisa Thain, MD, FRCPC (London, ON, CANADA, )*

### **Objectives:**

The purpose of this study was to determine if there is an osseous component, in the form of increased humeral head retroversion, that may contribute to the range of motion(ROM) differences observed between the dominant(DOM) and nondominant(NDOM) arms of competitive baseball players.

### **Methods:**

All subjects (N=20players and N=6controls) underwent bilateral CT scans to determine the angle of humeral head version for both the DOM and NDOM arms. Subjects were supine on the scanner table and held in a fixed position during the CT scans by a large Velcro strap. The angle of humeral head version was defined as the acute angle formed between the humeral head axis proximally and the trans-epicondylar axis distally. Active and passive ranges of motion(ROM) were also completed for both the DOM and NDOM arms of all subjects. With the subject supine on the examination table, the upper extremity being measured was fixed at 90degrees of abduction while external ROM and internal ROM were measured and recorded using a standard universal goniometer. Investigators were blind to arm dominance during all data collection throughout this study.

### **Results:**

A significant side-to-side difference in humeral head retroversion (mean diff =10.22;p<0.001) was found between the DOM and NDOM arms of the baseball players. All ROM measurements were also found to be significantly (p<0.05) different between the DOM and NDOM arms. No significant side-to-side difference was observed in humeral head retroversion for the group of controls (mean diff =3.17degrees) and there was no significant difference for any of the ROM measures when comparing their DOM vs NDOM arms. All shoulders without a past history of shoulder injury (N=35) were used to determine if the angle of retroversion correlated with any of the four ROM. A significant correlation was found for both passive external rotation (r=0.477;p<0.01) and active external rotation (r=0.523;p<0.01). Although not statistically significant, passive internal rotation and active internal rotation did exhibit strong trends (r=-0.291 p=0.09 and r=-0.266 p=0.12, respectively).

### **Conclusions:**

These results suggest that highly competitive baseball players have side-to-side differences in humeral head version that may contribute to the observed differences in side-to-side ROM. The knowledge of this possible osseous adaptation to the DOM arm should be taken into consideration during clinical evaluation of these athletes and could prove helpful in training prescription as well as the treatment and prevention of injury.

## **GENDER DIFFERENCES IN THE MUSCULAR PROTECTION OF THE KNEE IN BMI-MATCHED ATHLETES**

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### **Objectives:**

Female athletes participating in the same cutting and pivoting sports are more likely to rupture their anterior cruciate ligament than males. The volitional stiffness that can be developed across the knee joint by muscle during sports activities represents an important component to knee joint stability and injury prevention. The purpose of this study was to quantify the maximal volitional increase in rotational knee stiffness developed by size and sport-matched young males and females.

### **Methods:**

Twenty-four NCAA division I athletes (12 male, 12 female) competing in the high risk sports for ACL injury (basketball, volleyball, soccer) were compared with 28 collegiate athletes (14 males, 14 females) participating in non-pivot sports (cycling, crew, running). Male/female pairs were matched for age, height, weight, body mass index (BMI), shoe size, and activity level. A novel device was designed to test rotational knee laxity at varying knee angles. Tibial rotation was measured both at 30 and 60° of knee flexion, with and without maximal muscle co-activation.

### **Results:**

A gender effect was found, with females increasing volitional knee stiffness significantly less than males ( $p < 0.05$ ). Female athletes in the pivoting sports were found to have the lowest volitional increase in knee joint stiffness (171% vs. pivoting males -258%; non-pivoting females-198%; non-pivoting males-207%), despite being exposed to some of the best training available.

### **Conclusions:**

These collegiate female athletes participating in pivot sports were unable to volitionally increase their rotational knee stiffness to the same extent their male counterparts were. Focus on improving the active protection of the knee during rehabilitation and training may be instrumental in decreasing knee injury rates.

## **PROPRIOCEPTIVE AND KINESTHETIC DIFFERENCES IN ANTERIOR CRUCIATE RECONSTRUCTED KNEES: EFFECTS OF GRAFT CHOICE AND POSTOPERATIVE STABILITY**

*Spero Karas, MD (Chapel Hill, NC), Erica Booth, (Chapel Hill, NC), Kelly Spooner, PT (Vail, CO), Mike Decker, MS (Vail, CO), Mike Torry, PhD (Vail, CO)*

### **Objectives:**

Identify proprioceptive and kinesthetic differences in ACL reconstructed knees comparing patellar ligament grafts, quadrupled hamstrings grafts, and post-operative KT-1000 arthrometry measurements.

### **Methods:**

Nineteen patients (mean age= 29, average 90 months out from surgery) with ACL reconstructions utilizing autogenous quadrupled gracilis-semitendinosus grafts (ACL-h) were compared to twenty-five patients (mean age=31, average 63 months out from surgery) with autogenous patellar ligament reconstructed knees (ACL-p). There were no concomitant injuries in either of the reconstruction groups. Twenty-three ACL deficient (ACL-d) knees and ten uninjured knees (ACL-c) served as controls. All post-operative patients had completed a rehabilitation program and had returned to unrestricted activity. All knees underwent KT-1000 arthrometry to evaluate knee stability prior to testing. Analysis was performed with a Cybex® data processor to evaluate proprioception (perception of joint position) and kinesthesia (perception of changes in joint motion). Data was statistically analyzed with ANOVA and Bonferroni-Dunn tests.

### **Results:**

There were no statistically significant differences in KT measurements comparing ACL-p and ACL-h knees ( $p < .05$ ). However, there was a significant difference in KT arthrometry when ACL-h knees were compared to ACL-c knees ( $p < .05$ ). This difference was not present when comparing ACL-p knees to ACL-c knees. There was a statistically significant difference ( $p < .0083$ ) when comparing the proprioceptive and kinesthetic sensation of ACL-p and ACL-h knees to ACL-d knees. There was no difference in proprioception and kinesthesia between ACL-p and ACL-h groups.

### **Conclusions:**

Our study demonstrates that autogenous patellar ligament and autogenous quadrupled hamstrings ACL reconstruction restores proprioceptive and kinesthetic sensation when compared to ACL deficient knees. In spite of a significant difference in KT-1000 arthrometry when comparing ACL-h knees to ACL-c knees, there was not a significant difference in proprioceptive and kinesthetic sensation when the two types of reconstructions are compared to controls. In conclusion, ACL reconstruction with autogenous patellar ligament grafts and autogenous hamstring grafts both restore proprioceptive and kinesthetic sensation to the knee equal to that of uninjured knees.

## **THE EFFECT OF ESTROGEN ON MATERIAL AND MECHANICAL PROPERTIES OF THE INTRA & EXTRA-ARTICULAR KNEE STRUCTURES**

*Elizabeth Arendt, MD (Minneapolis, ), Kenji Sudoh, BS (Minneapolis, ), Aaron Mueller, BS (Minneapolis, MN)*

### **Objectives:**

Female athletes have a higher incidence of noncontact knee injuries compared to male athletes in similar sports; with anterior cruciate ligament (ACL) tears being the most common. Different arguments for this gender discrepancy have been postulated, including: anatomical, neuromuscular, hormonal, and more. Of these arguments, the contribution of hormonal differences to decreasing the ligament strength is unclear. The purpose of this study is to evaluate the effect of estrogen on material and mechanical properties of the intra and extra-articular knee structures.

### **Methods:**

26 young female rhesus monkeys were divided into two surgical groups, sham (n = 12), and ovariectomized (n = 14). Both groups were kept in similar facilities with similar food and exercise levels. Two years after the surgery, animals in both groups were euthanized and the knees harvested. The ACL and central third of the patellar tendon (PT) were pulled to failure at 100 % / second on a hydraulic MTS testing machine (MTS corporation, Edina, MN, USA). During testing, the load and displacement were recorded. Statistical analysis was performed using a Student's T-test, with a p-value < 0.05 being considered significant.

### **Results:**

There was found to be no significant difference in any material or mechanical parameter between the control and ovariectomized groups for either ACL or PT (Table 1).

### **Conclusions:**

This study shows that estrogen has no effect on the material or mechanical properties of both intra and extra-articular knee structures. Thus, effort should be made to evaluate the effect of other parameters that could be effecting female athlete's knee injury rate.

## **GENE ENHANCED-TISSUE ENGINEERED REPAIR OF THE MENISCUS**

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### **Objectives:**

Tears within the avascular zone of the meniscus have been shown not to heal. Currently no reproducible technique has been developed for repairing these lesions. The concept of local peptide delivery using engineered cells [Gene Enhanced Tissue Engineering] is an attractive new technology with applications for meniscus repair in the avascular zone.

### **Methods:**

Cell culture: Meniscal fibrochondrocytes were obtained from menisci of adult bovine knee joints. Plasmid DNA, Oligonucleotide primers, and RT-PCR: Oligonucleotide primers were manufactured and used to generate cDNA fragments of the human IGF-1 genes by RT-PCR, as previously described [Mason et al., 1998]. When the cells became confluent, they were seeded onto resorbable polymer scaffolds for implantation into bucket handle tear defects in bovine menisci.

Assembly of Tissue Constructs: IGF-1 transduced cells were seeded onto PGA polymer scaffolds @1E6/100ul. Surgical Procedure: Menisci were harvested from bovine knee joints. Segmental wedges were cut from whole menisci and a bucket handle tear was made in the inner one-third [white zone] of the meniscus. The tear was either left empty [control], filled with a cell construct minus IGF-1 [Exp. 1], or filled with a cell construct containing IGF-1 transduced cells [Exp.2]. All bucket handle tears were repaired with a meniscal arrow [Bionx, Inc]. Menisci were then transplanted subcutaneously onto the dorsum of athymic rats and allowed to incubate in vivo for either two or four weeks.

### **Results:**

In vitro: Meniscus cells were easily grown in culture and transduced. Northern blot analysis confirmed IGF-1 message being upregulated. ELISA demonstrated synthesis into medium with active IGF-1 peptide. The quantity of IGF-1 synthesized was 6.25pg /1E6 cells/24 hours. Non transduced meniscal cells had no detectable IGF-1 in the media supernatant.

In vivo: Histology showed control menisci constructs were not repaired. Implantation of cells minus IGF-1 gene filled the gap between the tear bridging the gap. The experimental IGF-1 grafts completely healed the tear and demonstrated integrative repair with significant collagen deposition and extensive reorganization of the repair site.

### **Conclusions:**

Our laboratory has developed new cell therapies that include introduction of genes known to be anabolic for meniscal cells. Initial studies have shown biological or integrative repair occurring in these experiments. The clinical implication of these results would be the repair of tears in the avascular zone.

## **RECONSTRUCTION OF POSTERIOR CRUCIATE LIGAMENT (PCL) RUPTURES UTILIZING THE ONLAY TECHNIQUE.**

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### **Objectives:**

This study documents the short-term clinical outcomes in patients who sustained posterior cruciate ligament (PCL) ruptures reconstructed using an achilles tendon allograft with a tibial onlay and two tunnel technique.

### **Methods:**

Thirty-one patients with 33 PCL ruptures have been followed in a prospective outcome study. Every patient was evaluated by the senior author regarding clinical outcome. All of the patients had sustained knee dislocations. Injury data has been combined with radiographs and clinical exams to evaluate these patients. Thirteen knees had compass hinge external fixators in addition to their reconstruction.

### **Results:**

Thirty-two of the knees had clinical stability (0 or 1+) at an average follow-up of 14 months (range 3-26). Twenty-three knees had no laxity, while an additional nine had 1+ laxity. One patient had 2+ laxity at the most recent follow-up. There was one intraoperative failure requiring revision three days later. Knee motion demonstrated a mean extension of 3° (range 0-15) and a mean flexion of 112° (range 75-140). Twenty-three knees had meniscal tears, with 8 medial, 8 lateral and 7 having both medial and lateral. One patient sustained an intraoperative vascular injury requiring repair. Four patients sustained an arterial injury at the time of their dislocation, while 9 patients had a peroneal nerve injury. Six patients had associated tibial plateau fractures.

### **Conclusions:**

Chronic mild to moderate posterior sag is a frequent problem following PCL reconstruction, especially following multi-ligamentous knee injuries with aggressive post-operative rehabilitation. PCL reconstruction using a partial open onlay technique with two bundles provides good results following knee dislocations. Ninety-seven percent of our patients had a stable PCL at their most recent clinical follow-up. Seventy percent had no laxity at all on exam. The onlay technique provides excellent stability following multi-ligamentous knee injuries over short-term follow-up.

## **A CONTROLLED STUDY OF AUTOLOGOUS CHONDROCYTE IMPLANTATION VERSUS DEBRIDEMENT FOR FULL-THICKNESS ARTICULAR CARTILAGE LESIONS OF THE FEMUR: RESULTS AT 3-YEARS.**

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### **Objectives:**

Results of autologous cultured chondrocyte implantation (ACI) for articular cartilage lesions of the knee (femoral condyles and trochlea) generally demonstrate effectiveness in 80%-85% of cases. However, no studies have compared these results to those of a control group. This is the first prospective, concurrently controlled study to directly compare ACI to an alternative treatment.

### **Methods:**

Patients were prospectively followed and evaluated pre-operatively and at 3 or more years post-treatment using the modified Cincinnati Score. Adverse events, including treatment failures were collected using standardized forms. Failures were included in the analysis and scored as a "2" with all symptoms present.

### **Results:**

86 (debridement) and 58 (ACI) patients were assessed. Mean age 36 (debridement) and 37 (ACI) years. Mean total defect area 4.0cm<sup>2</sup> (debridement) and 4.8 cm<sup>2</sup> (ACI). 17% (debridement) and 22% (ACI) had multiple lesions. 17% (debridement) and 41% (ACI) had failed prior abrasion/drilling/microfracture. Patients were on workers compensation insurance in 14% of debridement and 36% of ACI cases. Mean baseline overall Cincinnati knee scores were 4.4 for the debridement and 3.2 for the ACI cohorts. Results at 3 years indicate improvement in 55% of debridement and 83% of ACI (p<0.001). Mean overall clinician score at follow-up (±SD): 5.6±2.4 (debridement) vs. 7.0±2.5 (ACI), p<0.001. Mean overall Cincinnati score decreased with increasing lesion size in debridement patients but was unchanged in ACI: ≤3cm<sup>2</sup>: 6.0 vs. 7.0, >3cm<sup>2</sup> - ≤6cm<sup>2</sup>: 5.9 vs 6.8, >6cm<sup>2</sup>=5.2 vs 7.1. Adverse events or continued symptoms required 26 reoperations in 17 patients (debridement) and 20 reoperations in 19 patients (ACI). Treatment failure occurred approximately 3 times more often in debridement than in ACI patients.

### **Conclusions:**

ACI is more likely to result in improvement, and produces a higher level of function and greater probability of return to sport than debridement alone. These differences are greatest in patients with larger lesions.

## **CORRELATION OF PROXIMAL HUMERUS PHYSEAL CHANGES WITH SYMPTOMS IN SKELETALLY IMMATURE THROWERS**

*Scott Mair, MD (Lexington, ), Timothy Uhl, PhD (Lexington, KY), Rudy Robbe, MD (Lexington, KY), Kathleen Muldoon, MD (Washington, DC)*

### **Objectives:**

Shoulder pain in children and adolescent throwing athletes is often attributed to "little league shoulder". Symptoms are thought to be due to stresses that occur at the proximal humeral physis. The diagnosis is confirmed by radiographs that show physeal widening, demineralization, sclerosis, and fragmentation. The purpose of this study was to determine whether radiographic findings of "little league shoulder" correlated with symptoms in skeletally immature throwers.

### **Methods:**

40 male youth baseball players, age 8-15, were studied during the peak of their season. The subjects were queried as to whether they had ever had pain in the throwing shoulder, whether they had aching after throwing during the current season, and whether they presently had symptoms with throwing. Subjects then underwent bilateral anteroposterior radiographs in internal and external rotation. Radiographs were then reviewed and interpreted by a radiologist blinded as to the right or left shoulder. This radiologist first made a judgment as to whether either shoulder showed subjective findings consistent with "little league shoulder", then obtained objective measurements of physeal width.

### **Results:**

In 20 athletes, subjective findings consistent with "little league shoulder" were determined to be present. In all of these subjects, the radiographic physeal changes were present in the dominant arm. 10 athletes reported some history of pain in the throwing shoulder, 5 had aching after throwing during the current season, and 3 presently had symptoms with throwing. Subjective findings of "little league shoulder" were compared to history of pain ( $p=.46$ ), aching after throwing during the current season ( $p=.02$ ), and present symptoms ( $p=.07$ ). Differences in physeal width in the dominant and nondominant arm were compared to history of pain ( $p=.04$ ), aching after throwing during the current season ( $p<.01$ ), and present symptoms ( $p<.01$ ).

### **Conclusions:**

In skeletally immature baseball players, symptoms involved with throwing do have some correlation with radiographic findings found in "little league shoulder". Symptoms that occur in young throwing athletes may be related to stresses at the proximal humeral physis. However, demonstrable radiographic changes at the proximal humeral physis are relatively common in skeletally immature throwers, and many of these athletes are asymptomatic.

## **ACHILLES TENDON RUPTURE: BIOMECHANICAL PROPERTIES OF VARIOUS SUTURE REPAIR TECHNIQUES IN A CADAVERIC MODEL**

*Steven J. Lee, MD (New York, NY), Stephen Nicholas, MD (New York, NY), Kenneth Akizuki, MD (New York, NY), Simon Ben-Avi, PhD (New York, NY), Ian Kremenik, MEng (New York, NY)*

### **Objectives:**

To compare the biomechanical strength and characteristics of varying suture strands and techniques for Achilles tendon repair.

### **Methods:**

24 fresh frozen human achilles tendons were transected 4 cm proximal to the tendon insertion. These were repaired with #2 Ethibond suture using one of three repair techniques (Modified Kessler, Krackow, or Bunnell), while varying the number of strands that crossed the repair (2,4,6,8). Unidirectional tensile loading to failure was performed on a MTS machine. Load-displacement values analyzed included peak load at clinical failure, stiffness, amount of elongation at failure, and method of failure.

### **Results:**

Increasing the number of strands produced a significant increase in the strength of the repair (2 strands 108N, 4 strands 146N, 6 strands 196N, 8 strands 266N), except between 2 and 4 strands ( $p = 0.068$ ). The type of repair used did not significantly alter the repair strength (Kessler 170N, Krakow 171N, Bunnell 194N). 8 stranded repairs were significantly stiffer than 6, 4, or 2 strands ( $p = 0.003$ ), while no difference in stiffness was found between repair types. 2 strands elongated significantly less than 4, 6, 8 stranded repairs ( $p = 0.012$ ), and the Krackow repair elongated less than the Bunnell repair ( $p = 0.031$ ). The most common site for failure was either at or next to the knot independent of the number or type of repair.

### **Conclusions:**

While repair techniques have been extensively studied in the hand literature, little has been written for achilles tendon repairs. Obvious differences of achilles tendon repairs include the larger surface area for sutures, the higher forces transmitted across the repair, and the lack of tight and unyielding tunnels. Based on this study, increasing the number of strands that cross the repair site increases the strength of the repair. The type of repair that is used however, does not alter the ultimate strength or stiffness characteristics. Given the current rehabilitation protocols that emphasize early range of motion and weight bearing, more consideration should be given to increasing the number of strands that cross the repair site rather than the type of repair used.

## **CLINICAL OUTCOME OF HAMSTRING TENDON AUTOGRAFT ACL RECONSTRUCTION WITH BIOABSORBALE INTERFERENCE SCREW FIXATION**

*Stephen E. Lemos, MD, Donald A. Randolph, Jr., MD, Clarence L. Shields, Jr., MD, William P. H. Charlton (Los Angeles, CA)*

### **Objectives:**

ACL injury occurred through contact or noncontact mechanism. Previous studies strongly support noncontact mechanisms for ACL tears in women.

So, the menstrual cycle and estrogen concentration may play an important role in ACL functions. However, it has yet to be determined whether fluctuations in estrogen levels affect the laxity of ACL in women. The objective of this study was to determine whether ACL laxity in females changes during their menstrual cycle clinically. In this study, we hypothesized that ACL functions in females were dependent on the menstrual cycle.

### **Methods:**

Ten males and 17 females were examined. They were all volunteers and understood the content of our research. Seventeen females (21~23 years old, average 21.5 years old) have regular menstrual cycles (28~34 days) and no history of knee injury.

Measurements of their knees using KT-2000 were performed 3 times every week during 4 weeks. From their basal body temperatures and the concentration of the E2 and progesterone, we defined the three phases; follicular, ovulatory, and luteal.

Ten males were 21~23 years olds, average 21.5 years old. Measurements of their knees using KT-2000 were measured 3 times every week during 3 weeks. However, they did not measure the female hormone levels in their blood. We defined the three phases for analysis; first, second, and third week. We evaluated the anterior displacement, the difference of anterior displacement, and anterior terminal stiffness at 30 pounds among three phases in female and male respectively. ANOVA was carried out for comparison between phases, with p values of less than 0.05 being considered significant.

### **Results:**

With the anterior displacement and the difference of anterior displacement, there were no statistically differences among three phases in both females and males.

With anterior terminal stiffness, the significant difference between follicular and luteal phases in the females. P value is 0.01. However, regarding other phases in females, and among all phases in the males, there were no significant differences.

### **Conclusions:**

From our results, there were no significant differences among 3 phases in the anterior displacement, however, anterior terminal stiffness during the follicular phase was significantly less than that during the luteal phases. At the very least, we showed that ACL stiffness in females was dependent on the menstrual cycle. The possibility exists that the higher risk of ACL injury in females may be due to females hormones.

## **DEVELOPMENT AND VALIDATION OF THE NEW INTERNATIONAL KNEE DOCUMENTATION COMMITTEE (IKDC) SUBJECTIVE KNEE FORM**

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### **Objectives:**

A committee of international knee experts redesigned the original IKDC Knee Ligament Form. As a result of this the IKDC Subjective Knee Form was created as a knee-specific, rather than a disease-specific, measure of symptoms, function and sports activity that is appropriate for all forms of knee pathology. The purpose of this study was to evaluate the reliability and validity of the new IKDC Subjective Knee Form.

### **Methods:**

Development of the IKDC Subjective Knee Form included generation and field-testing of 48 items on 366 patients. Content and statistical properties of the items were considered to reduce the final version of the IKDC Subjective Knee Form to 18 items. To provide evidence for reliability and validity, the final version was administered to a second sample of 533 patients (mean age 37.5 yrs., 52.6% males, 28% ligament injuries, 20% meniscal injuries, 20% patellofemoral problems, 18% osteoarthritis). The SF-36 was concurrently administered. Analyses were performed to determine the factorial structure, internal consistency, test re-test reliability and validity. A Rasch analysis was performed to detect differential item function (DIF) related to age, gender and diagnosis.

### **Results:**

Factor analysis revealed a single dominant component, making it reasonable to combine all items into a single score. Coefficient alpha was .92 indicating that all items contributed to the consistency of measurement. Test re-test reliability was .95 (95% CI .81 to .99). The IKDC Subjective Knee Form score was related to concurrent measures of physical function ( $r=.47$  to  $.66$ ) but not to concurrent measures of emotional function ( $r=.16$  to  $.26$ ). Analysis of DIF indicated that with few exceptions the items functioned similarly for males vs. females, young vs. old and for those with and without ligamentous, meniscal and patellofemoral problems.

### **Conclusions:**

The IKDC Subjective Knee Form is a reliable and valid knee specific measure of symptoms, function and sports activity that is appropriate for individuals with a wide variety of knee problems. Use of this instrument will simplify administration in the office setting and will permit world-wide comparisons of outcome across groups with different knee pathologies.

